

Mass Flow Measurement of Biofuels using Electrical Capacitance Tomography

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Extended Abstract

Mass Flow Measurement of Biofuels using Electrical Capacitance Tomography

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1 INTRODUCTION

Biomass provides 10% of the global energy supply and electricity generation from biomass and waste is expected to increase by a factor of 4 by 2030. Currently efficiency of biomass power generation is poor and IEA targets improvements from 18% to 25% by 2030 [1]. Such increases in efficiency will require significant new technology and accurate real-time measurement of the flow of these highly variable solids will be a key factor in this efficiency improvement.

Electrical Capacitance Tomography (ECT) has been used to measure flow structure and mass flowrate of a number of materials including dry solids. It has previously been shown that details of the flow structure may be measured and that the overall mass flowrate of a distributed dry solid flow may be estimated. Here the effects of particle material, size and shape are investigated by comparing the flows of several different products of different physical properties and shape in a simple gravity-driven flow in a pipe of 120mm internal diameter.

2 ECT OPERATION AND APPLICATION

Electrical capacitance tomography (ECT) allows high speed imaging of permittivity distribution and velocity measurement through x-correlation. It is non-intrusive, capable of industrial application and can give accurate mass flow measurement of dry solids [2].



Figure 1 shows a typical ECT research system where the sensor is mounted as a clamp-on device, the capacitance measurement is made in a conventional rack-type unit, and the image processing is undertaken on a laptop PC. The sensor is connected to the measurement unit by co-axial leads - the advantages of this arrangement is that different sensor heads may be used with the same electronics, and software improvements are easily incorporated. Communication between the PC and the capacitance measurement unit is via high-speed ethernet.

Fig. 1 – Commercial ECT System

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ECT may also be used in an integrated flowmeter allowing up to 5000 frames per second of ECT images, concentration profiles and velocity profiles to be recorded. Mass flowrate may be estimated by integrating velocity, density and concentration as described in [2].

3 EXPERIMENTAL SETUP AND RESULTS

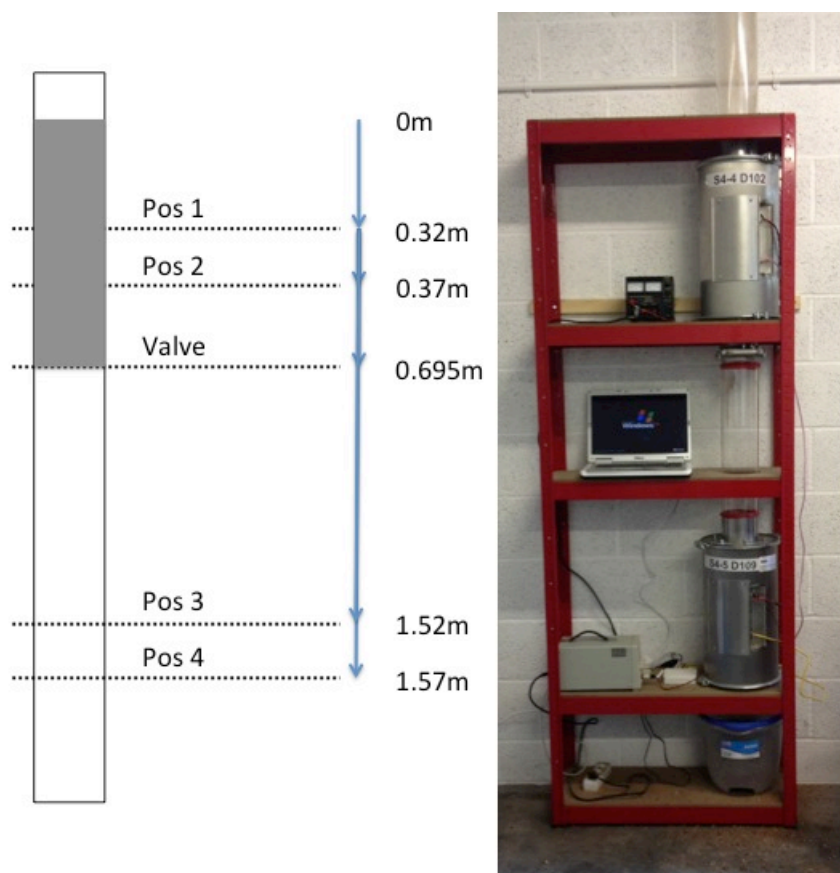


Fig. 2 Biofuels experimental rig

The experimental arrangement for the tests reported here is shown in Figure 2. Two ECT sensors were mounted vertically in tandem. The top sensor above a plate valve was filled with the material on test and the valve was opened and ECT measurements made in both sensors. Materials tested were wood pellets, wheat and cocoa shells.

As the valve plate is removed the solids start to mobilise. Above the plate a disruption front propagates up through the solids bed, while below the plate there is a dispersed flow of solids in air.

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The plug of solids disrupts first near to the wall after valve opening then around the perimeter and up the wall of the pipe. The central plug of solids accelerates downwards, remaining as a coherent elongated cylinder at high relative density.

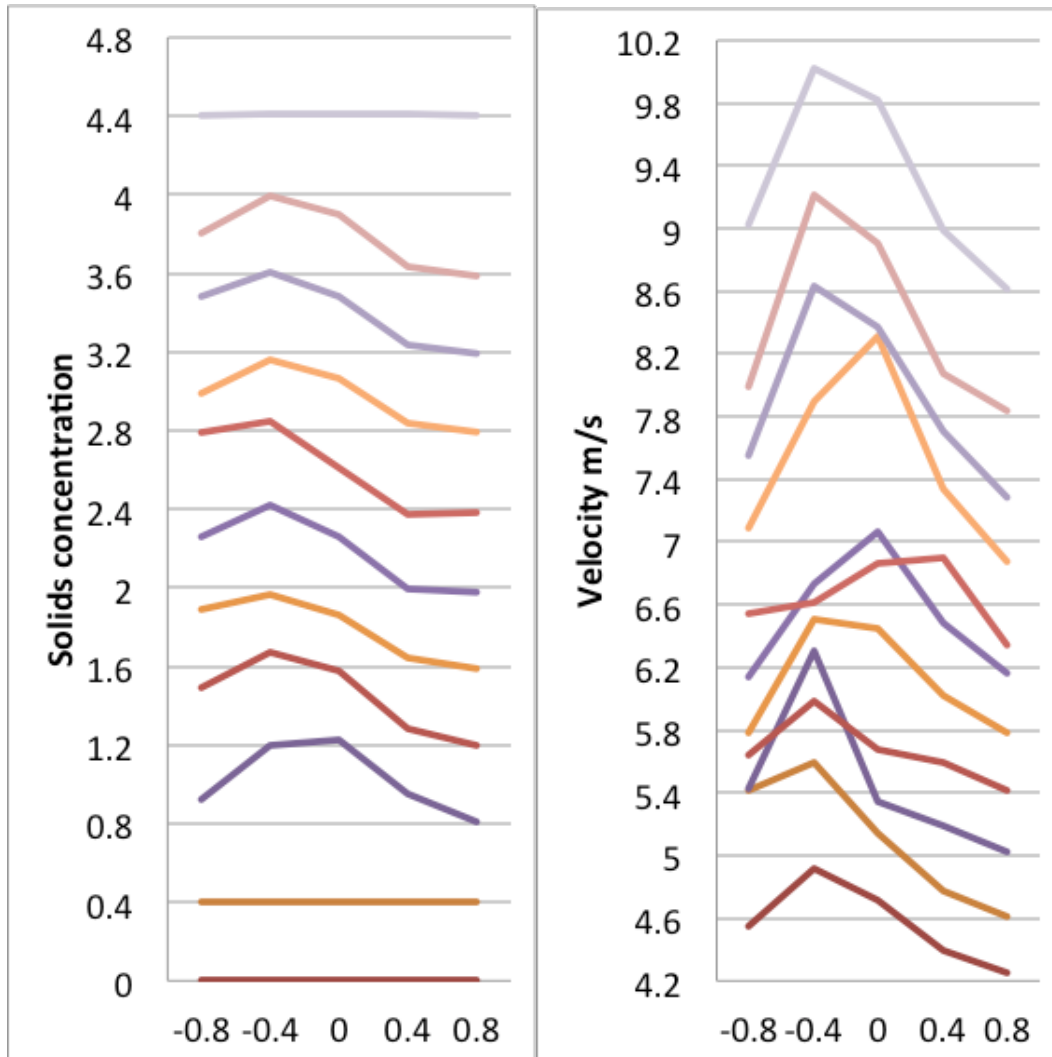


Fig. 3 Solids concentration (left) and velocity (right) against radial position on a chord – position 3. Curves are at 0.1 second intervals from bottom to top, shifted up by 0.4 units each time.

It can be seen from Figure 3 that the concentration and velocity are skewed and that although most solids pass down the left-hand side of the pipe, the velocity distribution moves across to the right for the middle part of the test.

Figure 4 shows the centre-line velocity is fairly steady throughout the test – since the flow is accelerating from rest under gravity this shows that the plug of solids disrupts at approximately the same position for each section. In other words the compact plug sliding down continues to disrupt into disperse flow at about the valve position for the entire test, as if a virtual valve were present.

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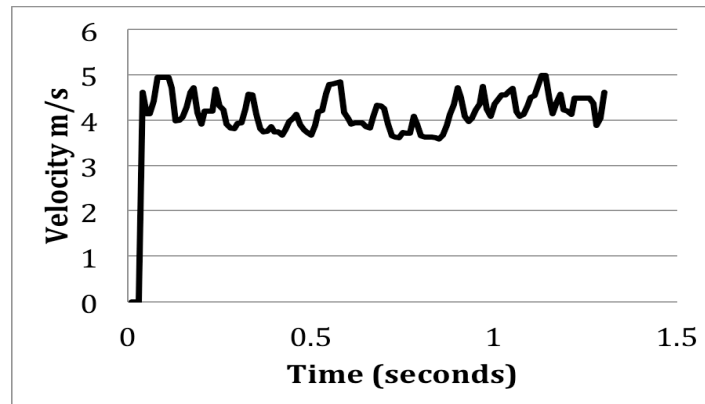


Fig. 4 Centre-line velocity against time – position 3.

The concentration and velocity images can be integrated to give total mass flowrate as shown in Table 1.

Table 1 – Mass flowrate measurement accuracy (10 samples of each)

	Mass kg	Estimated mass kg	Mean error %	Standard deviation %
Wood pellets	5.699	5.725	-0.46%	1.22%
Wheat	6.129	6.201	1.17%	1.99%
Cocoa shells	1.256	1.251	-0.37%	4.03%

4 CONCLUSIONS

ECT can provide detailed analysis of the concentration and velocity of the flow of dry solids. In the case of the gravity flow of dry biofuels the nature of the particles affects the way in which the solids flow and ECT measurements can show this in detail. The solids plug above a suddenly-removed plate valve slides and disrupts at approximately the same rate such that the dispersed flow starts at about the valve position throughout the test, although the velocity and concentration profiles can show independent asymmetry.

ECT-based solids flowmeters have the potential to advance the accuracy of measurement of these complex flows and Mean flowrate errors of less than 1% and standard deviation of errors of 1% to 4% are consistent with previously reported accuracy of ECT-based mass flowmeters.

4 REFERENCES

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